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Optimization and Investigation of Effect of Laser Beam Machining (LBM) Process Parameters on C-45 Steel Material

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Abstract: *Laser machining is a popular manufacturing process utilized to cut various types of materials economically. In this paper laser machining of Mild Steel has been investigated. Mild Steel is soft because of its high strength and malleability LBM is a precise and efficient manufacturing route in many applications. In the present research, Taguchi Method was used for analysis of effect of LBM process parameters on surface roughness (SR) on C-45 mold steel material. Different parameters like gas pressure, laser power and cutting speed are used to optimize surface roughness by MINITAB 19. Taguchi orthogonal array L9 along with ANOVA is used for optimizing three different parameters so that minimum surface roughness is* obtained.

Keywords: *LBM, Taguchi Method, ANNOVA, SR.*

1. INTRODUCTION

As per the latest trend in manufacturing for processing of advanced engineering materials laser beam cutting process is widely used. In this process focused laser light is imparted on work piece material to melt the material locally. Melted material is then come out of cavity called as kerf. Oxygen is used as assist gas which causes exothermic reaction to drag the melt away from the kerf. Laser cutting process can be effectively used for complicated design requirements and unusual size of work piece. In this process no need of post processing for cut parts as they are having good surface finish.

Laser cutting of metals has become a reliable technology for industrial production. Currently, it is considered as a feasible alternative to mechanical cutting and blanking due to its flexibility and ability to process variable quantities of sheet metal parts in a very short time with very high programmability and minimum amount of waste. Laser cutting does not need special fixtures or jigs for the work piece because it is a non-contact operation. Additionally, it does not need expensive or replaceable tools and does not produce mechanical force

that can damage thin or delicate work pieces. Laser cutting have many principles as the same as the conventional fusion cutting methods. But the laser cutting excels in applications requiring high productivity, a high edge quality and minimum waste, due to the fast and precise cutting process. Mild steel is a daily used material and dominantly used in the laser cutting industry. In the last few years, the rapid development of high power fiber lasers provides more efficient, robust new technologies for materials process.

2. EXPERIMENTATION

2.1 Methodology of Experiment

Some parameters like gas pressure, laser power and cutting speed etc. play an important role in minimum SR. So as to overcome the existing problems, few optimization techniques have to be incorporated. Based on the mentioned parameters the following study was conducted to achieve the objective. Once the root cause of the problems which impacted the SR was identified and objectives were set to overcome the problem. Based on the observation, Taguchi method was followed to design the experiment to study the major contributing factors. Minitab-19 software was used to optimize the DOE using Taguchi techniques.

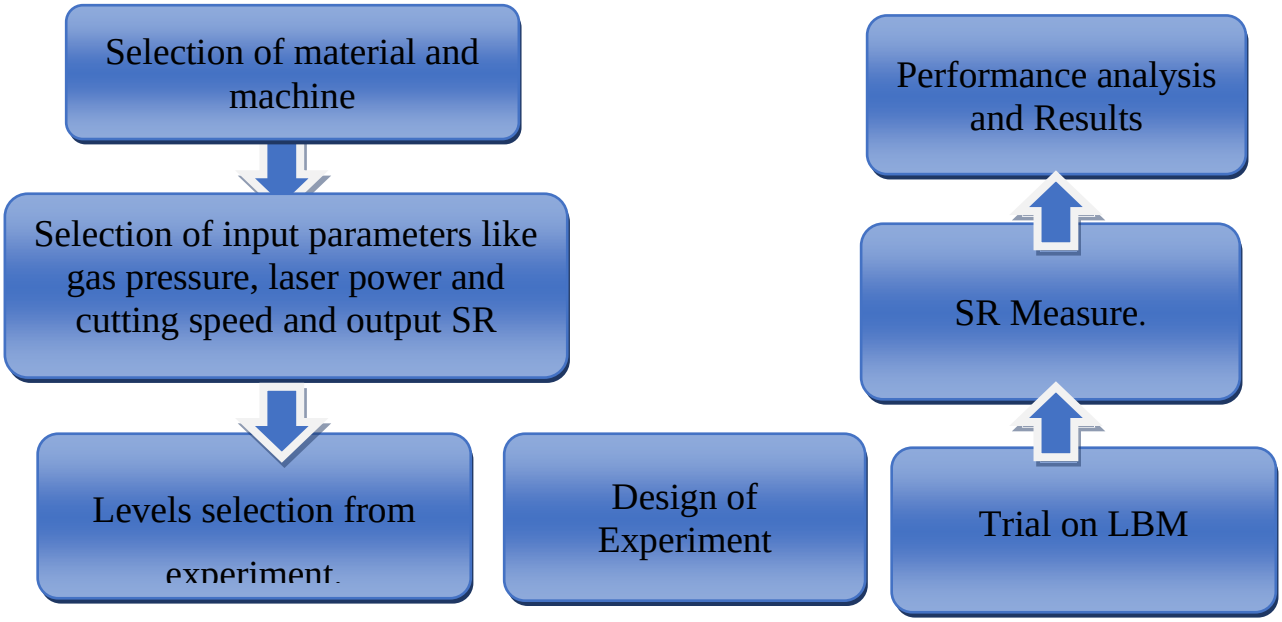

Figure *Flow chart of methodology*

2.2 Experimental Machine Selection

Table 1. *LBM machine Specification*

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Brand	SIL
Laser Source	Up to 1000W
Laser Wavelength	1080nm
Laser type	Fiber Laser
X axis Stroke	2050 mm
Y Axis Stroke	3050 mm
Z Axis Stroke	250 mm

Figure 2. *LBM Machine*

2.3 Selection of material

C-45 Steel

- High tensile strength.
- High impact strength.
- Good ductility and weldability.
- A magnetic metal due to its ferrite content.
- Good malleability with cold-forming possibilities.

Figure 3 *Selection of material*

Table 2 *Chemical Properties*

Element	Content
C- Carbon,	0.42-0.50 %
P- Phosphorus,	0.040 %
Si-Silicon	0.37 %
Mn- Manganese,	0.50-0.80 %
S- Sulphur,	0.050 %

3. RESULTS AND DISCUSSION

To get complete understanding of effects of input parameters gas pressure, laser power and cutting speed on output SR, you usually assess signal to noise ratio or main effects plot for means. For this purpose, Minitab 19 statistical software has been used. SR have been done. ANOVA has been conducted to find out effect each parameter on SR and linear regression model has established to predict values of SR.

3.1 Experimental Result

Table 3 shows L9 OA with measurement of SR for runs one to nine. It also shows S/N ratio for the all nine experiments.

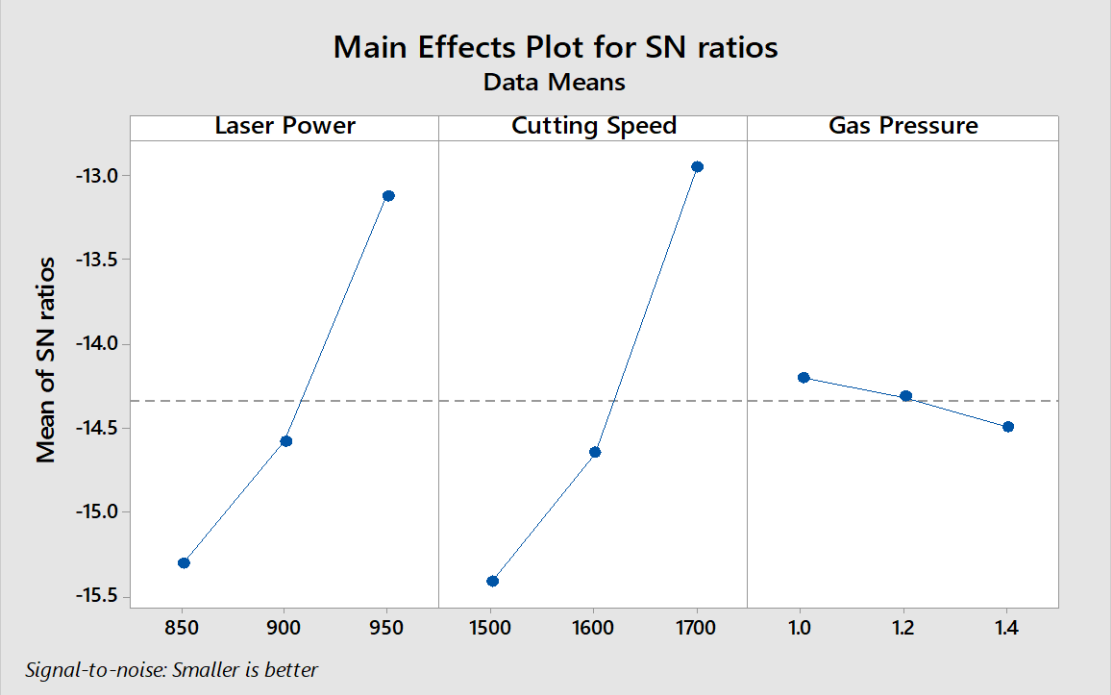
Table 4 *L9 orthogonal array with response characteristic.*

Experiments	Input Factors			Output Responses	
Trial No.	**Laser Power**	**Cutting Speed**	**Gas Pressure**	**SR**	**S/N Ratio**
1	850	1500	1.0	6.91	-16.7896
2	850	1600	1.2	5.22	-14.3534
3	850	1700	1.4	5.11	-14.1684

4	900	1500	1.2	6.12	-15.7350
5	900	1600	1.4	7.09	-17.0129
6	900	1700	1.0	4.18	-12.4235
7	950	1500	1.4	4.86	-13.7327
8	950	1600	1.0	4.67	-13.3863
9	950	1700	1.2	4.09	-12.2345

The S-N ratio values are calculate with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

3.2 Main Effects of SR



Graph 1 *Main Effects Plot for S/N Ratio*

From main effects plot for S/N ratio, the optimal input parameters were Laser Power 950 watt (level 3), Cutting speed 1700mm/min (level 3) and Gas Pressure 1.0 bar (level 1).

3.3 ANOVA Result

To decide two assessments of populace difference, one dependent on between tests fluctuation and other dependent on inside example change. At that point the said two evaluations of populace fluctuation are contrasted and F-Test. Compare the determined estimation of F with the table estimation of F for level of opportunity at certain degree of importance. On the off chance that the determined estimation of F is equivalent

to or more prominent than the table an incentive at pre decide level of criticalness the invalid theory is dismissed in any case acknowledged. For this ANOVA table is readied. In this ANOVA table, the amount of squares (SS) because of autonomous variable and amount of squares because of blunder is independently given. Level of opportunity is the quantity of way one can choose the segments for a set up under limitations. On account of investigation there is loss of one degree in amount of squares because of relapse. Mean amount of squares are acquired by partitioning the amount of squares by dof, each for relapse and mistake. The mean amount of squares identified with mistake is called difference

Table 5 *ANOVA Result.*

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Laser Power	2	3.9355	1.9677	6.80	0.19	31.24
Cutting Speed	2	2.4281	1.3640	4.19	0.27	19.27
Gas Pressure	2	5.6535	2.8267	9.76	0.12	44.88
Residual Error	2	0.5787				
Total	8	12.5958				

It shows table 4.7 that the Laser Power (31.24%), Cutting Speed (19.24%), and the Gas Pressure (44.88%) have major influence on the Surface Roughness. Contribution of Gas Pressure (44.88%) is highest among all three parameters hence it is most dominating parameter while Laser Power is least affecting parameter.

3.4 Development of Regression Model for SR

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for SR have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of SR correlates with each other.

Regression Equation –

SR = 26.95 - 0.01207 Laser Power - 0.00752 Cutting Speed + 1.08 Gas Pressure

Table number 5 gives comparison between experimentally measured and predicted SR by developed mathematical equation

Table 6 *Experimental and Predicted Values of SR*

Sr. No.	Experimental value	Predicted value	Error %
1	6.91	6.49	6.47
2	5.61	5.95	5.71
3	5.11	5.41	5.54
4	6.12	6.10	0.32
5	6.01	5.56	8.09
6	4.18	4.38	4.56
7	4.86	5.17	5.99
8	4.67	4.53	3.09
9	4.09	3.99	1.75

Difference between SR values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid.

3.5 Confirmation Experiment Result

Experiments was conducted for Laser Power at level 3, Cutting Speed at level 3 and Gas Pressure at level 1

Table 7 *Confirmation experiment result for SR*

Parameter	Predicted value	Experimental value	Error %
Surface Roughness (Ra)	3.78	3.83	3.16

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the SR value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 3.16%. This indicates that the experimental value correlates to the estimated value.

4. CONCLUSIONS

This study covers the observations about the Surface Roughness over the C-45 steel material by the process of Laser Beam Machine for the different input parameters to thoroughly study over the effect of Laser beam machining process on the C-45 steel material. Throughout the experimentation I got some results as under.

The combination of laser cutting parameters i.e. cutting speed, laser power and gas pressure were planned by L9 Orthogonal Array Taguchi method , based on the results obtained and derived analysis the following can be concluded.

1) The optimal solution obtained for SR based on the combination of laser cutting parameters and their levels is (i.e. laser power 950W, Cutting speed 1700 mm/min, and Gas pressure 1.0 bar).
2) ANOVA results indicate that cutting speed plays prominent role in determining the surface roughness. The contribution of Laser power, Cutting speed and Gas pressure to the quality characteristics surface roughness Ra is 31.24%, 19.27% and 44.88% respectively.
3) Cutting speed and Laser Power are the most significant parameters majorly affecting the surface roughness whereas the Gas Pressure is much smaller.
4) The optimal cutting parameters are determined using Taguchi methods match with the experimental values by minimum errors i.e 3.16% for SR
5) Through the developed mathematical models, any experimental results of surface roughness with any combination of laser cutting parameters can be estimated.

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